Executive Summary

The Design for the Environment (DfE) Program in EPA's Office of Pollution Prevention and Toxics (OPPT) is a voluntary, cooperative program that works in partnership with industry to develop and distribute pollution prevention and environmental and human health risk information on alternative products, processes, and technologies. The DfE Program develops technical information as well as information products such as case studies, video-conferences, training videos, and software to help industries and the public make cleaner choices in their business practices. All of the technical information developed by industry and the DfE Program is assembled in a document called a Cleaner Technologies Substitutes Assessment (CTSA). The CTSA forms the basis for subsequent information products and serves as a repository for all of the technical information (environmental and human health, exposure and risk, performance, and cost) that is developed in a DfE industry project. In the development of the CTSA, the DfE Program harnesses the expertise for which OPPT is best known: comparative and multi-media risk analysis, methods for evaluating alternatives for risk reduction, and outreach to industry and the public on pollution prevention topics.

The DfE Program uses a new approach to compare the risk, performance and cost trade-offs of alternatives in a decision focused evaluation. The approach evaluates a "use cluster," that is, a set of chemicals, processes and technologies that can substitute for one another in performing a particular function. This method is different from traditional pollution prevention approaches in that it does not focus strictly on waste minimization. Instead, the use cluster approach explicitly arrays alternative chemicals, products and processes allowing comparison of the risk management issues along with performance and cost in a systematic way. During the process of identifying alternatives, attention is focused on finding newer, cleaner substitutes as well as comparing traditional ones.

The DfE Program has been working with the screen printing industry to reduce risk and prevent pollution in the use cluster of screen reclamation. Partners in this effort include the Screen Printing Association International (SPAI) and the University of Tennessee's Center for Clean Products and Clean Technologies. Through a process of collecting information on currently existing screen reclamation alternatives and through a search for other promising options, the DfE Program and the screen printing industry have compared alternative and traditional screen reclamation products, technologies, and processes in terms of environmental and human health exposure and risk, performance, and cost. The results of this comparative assessment are contained in the Screen Reclamation Products Cleaner Technologies Substitutes Assessment.

Specifically, the Cleaner Technologies Substitutes Assessment (CTSA) is an analytical tool developed by the DfE Program for use by industry. The CTSA is intended to provide a flexible format for systematically comparing the trade-off issues associated with a use cluster. In the CTSA, traditional trade-off information such as cost and performance are brought together with environmental trade-off information including comparisons of environmental releases, human health and environmental exposures and risk, energy impacts, and resource conservation. The goal of the CTSA is to offer a complete picture of the environmental and human health impacts, cost and performance issues associated with traditional and alternative products, processes, and technologies so that businesses can make more informed decisions that fit their particular situation. Data contained in the CTSA will be used as the basis for information products designed to reach individual printers and suppliers who may not have the resources to utilize this information on their own.

Structure of the CTSA

The CTSA for Screen Printing Screen Reclamation focuses on the use cluster of screen reclamation. Screen reclamation is a process (to clean a screen a printer must remove the ink, the emulsion, and the haze from the screen) rather than a specific set of chemicals or technologies. Therefore, the CTSA is structured to evaluate screen reclamation systems. Systems typically include combinations of products designed to perform three functions: remove ink, emulsion, and haze and are typically sold as a system (see figure ES-1). Within any given screen reclamation system, the CTSA defines and evaluates the products used in the system and the chemicals that make up the products that are used in that system. The DfE Screen Printing Project has identified five individual methods and technologies through which screen reclamation can be performed.

Profile of Screen Reclamation Use Cluster

To develop comparative information on screen reclamation products and technologies, an array of different kinds of information about the industry is necessary. For example, in order to develop exposure estimates, information about the work practices, the number of employees, the chemicals used by employees, etc., is required. Chapter 1 in the CTSA provides background information, including market information, on the screen printing industry, and the screen reclamation process, in particular. It also describes some of the alternative cleaning technologies that could be applicable to the screen printing industry.

The screen printing industry is characterized by small businesses employing an average of 15 people or fewer. While screen printers can print on a variety of substrates, this effort focuses on the approximately 20,000 facilities who print graphic arts materials, such as fine art prints, billboard advertisements, point-of-purchase displays, posters, plastic banner wall hangings, original equipment manufacturing, and electronic equipment.

The screen printing process involves stretching a porous mesh material over a frame to form a screen. Part of the screen mesh is blocked by a stencil to define the image. A rubber-type blade (squeegee) is swept across the surface of the screen, pressing ink through the uncovered mesh to print the image defined by the stencil. After the screen has been used to print numerous images, it needs to be cleaned for future use. Many screen printing facilities reclaim their screens for reuse because the screen material is valuable and costly to replace. While screen reclamation techniques may vary significantly from one screen printer to another, two basic functions must be performed in order to restore a used screen to a condition where it can be reused: removal of ink and removal of emulsion (stencil). A third step, removing any remaining "ghost image" or haze, may also be required. (See Figure ES-1).

Screen Reclamation Methods

A variety of commercial products have been developed to perform each of these functions and a complementary series of products (e.g., a particular brand of ink remover product, emulsion remover product, and haze remover product) are often sold by manufacturers and distributors as a package. For the purposes of this project, the trade-off issues associated with

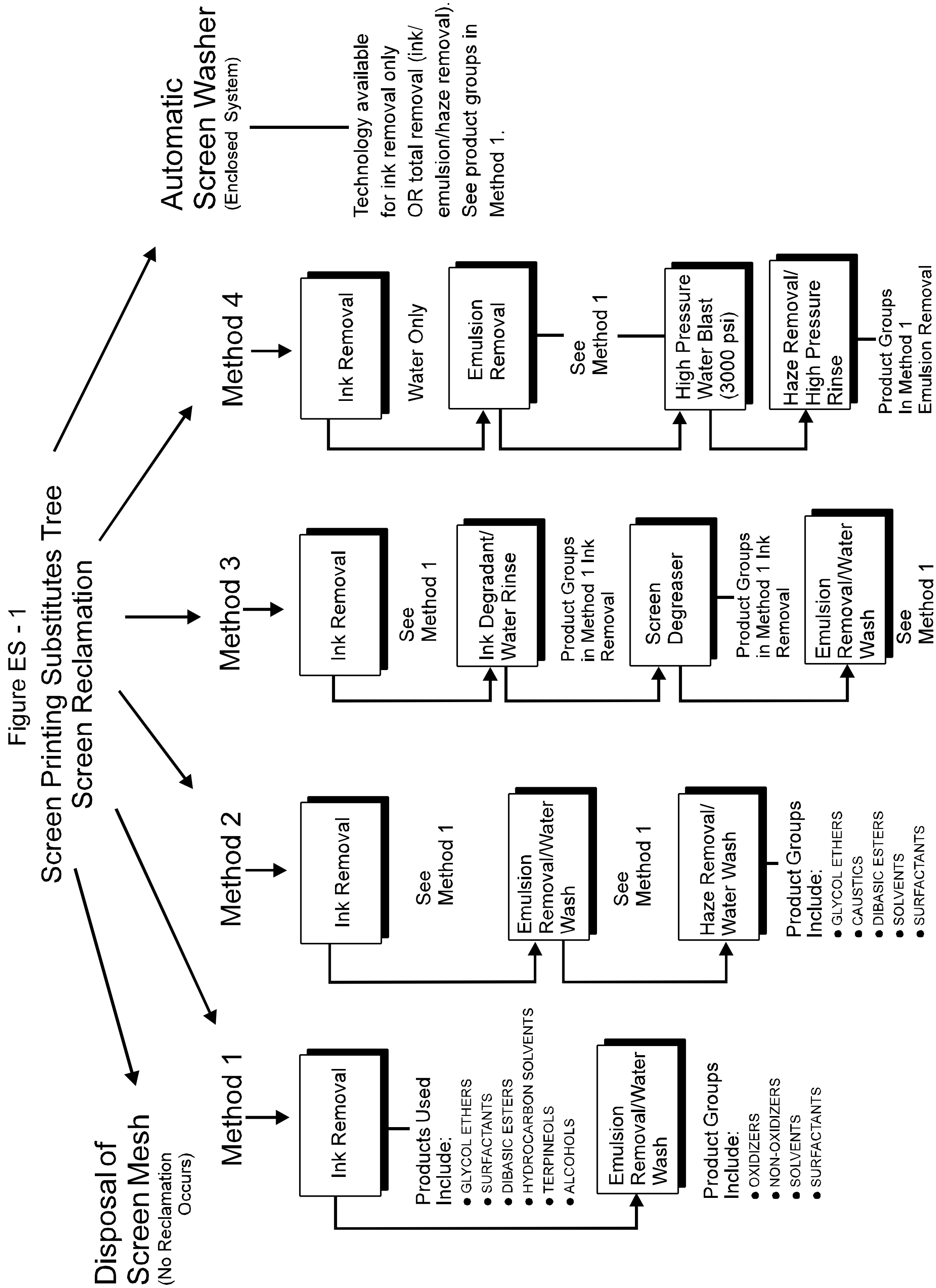

Figure ES - 1
Screen Printing Substitutes Tree
Screen Reclamation

a particular product system, consisting of an ink remover, emulsion remover and haze remover, are frequently assessed. Screen printers use these product systems in a variety of methods to reclaim screens.

DfE and SPAI identified five methods of undertaking screen reclamation; these are exhibited in Figure ES-1. Method 1 illustrates how screen reclamation is performed with products from the functional groups of ink removal and emulsion removal only. Under each functional group, some of the categories of chemicals that might be found in these products are listed. Some screen printers may use only products from these functional groups when reclaiming screens. More common among screen printers is the additional use of a haze remover in the screen reclamation process, as depicted in Method 2. Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 in that screen degreasers and ink degradants are used in the screen reclamation process. It also differs from Method 2 in that no haze remover is necessary. Method 4 employs both mechanical and chemical technologies to reclaim a screen. The use of a high-pressure water blaster eliminates the need for an ink remover in this method; however, emulsion and haze removers are still used. Method 5 involves the use of an automatic screen washer, an enclosed system that can be used for ink removal only, or as a complete system for screen cleaning.

Alternative Cleaning Processes

Because the Screen Reclamation CTSA is designed to be as comprehensive as possible, it presents information on the fullest consideration of cleaning alternatives. Some of these alternatives may be new or esoteric, others have been used in a cleaning function in other industries and are discussed in the Screen Reclamation CTSA because they may have the potential to be used in screen printing, perhaps with slight modifications. Some of these technologies include blasting methods, stripping methods, and methods that involve pulse light energy. Water-soluble stencils/emulsions also represent a product change that may affect other aspects of the printing and reclamation process (e.g., inks used).

The descriptions of the technologies that are highlighted in the CTSA are not exhaustive, but are intended to promote discussion of the use of potential alternative technologies in the screen reclamation process. Currently, some of these technologies are used in high-tech applications, and may not be economically feasible for the average screen printing establishment. However, further research into these technologies, and their continued development, may result in more cost-effective, easy-to-use applications in the screen printing industry.

One alternative technology evaluated for its potential in screen reclamation was a pressurized baking soda (sodium bicarbonate) spray. The pressurized baking soda spray, when combined with water, could remove solvent and water-based ink from a screen; the spray was ineffective in removing UV-curable ink. Emulsion could also be removed, with only a light haze remaining on the screen. Issues such as potential damage to the screen mesh and cost-effectiveness warrant further investigation, but equipment modifications could make the technology feasible for use in screen reclamation.

Chemical Profiles

Another set of information that is required to complete the comparative analysis of traditional and alternative screen reclamation products and technologies is chemical data. The screen printing industry identified seventy-two chemicals that are in use in screen reclamation. These chemicals comprise the screen reclamation use cluster and range from hydrocarbon solvents and glycol ethers, to surfactants, caustics and oxidizers. Specific information on each chemical was developed to support the risk assessment of screen reclamation products. Each chemical profile includes physical/chemical properties, industrial synthesis, aquatic toxicity, environmental fate, and a hazard summary. The regulatory status of each chemical is also provided as a ready reference, although the discussion of federal environmental regulations is intended for information purposes only and should not be used as a guide for compliance. Market profile information on each chemical, such as total U.S. production and total use in screen reclamation, was also developed. Included in this section is a generic categorization of some of the screen reclamation chemicals; this was developed in order to protect the proprietary nature of the alternative screen reclamation products submitted by manufacturers.

Methodologies

Because the Screen Reclamation CTSA is the DfE Program's first CTSA and will serve as a model for CTSA's developed for other DfE industry projects, it presents a full discussion of the methodologies that are used to develop the comparative environmental and human health risk information. The methodologies presented include: Environmental Releases and Occupational Exposure Assessment, Population Exposure Assessment, Risk Assessment, Performance Demonstration, Screen Reclamation Chemical Usage, and Cost Analysis. By presenting this information in its entirety, the DfE Program hopes to make the evaluation process completely visible so that others will be able to conduct some of these analyses independently.

Most of the methodologies that are applied in this analysis are standard methodologies that the Office of Pollution Prevention and Toxics' (OPPT) Existing Chemicals Program uses, except for the Performance Demonstration, Chemical Usage, and the Cost Analysis Methodologies that will be discussed in more detail later in this section. The human health hazard information was drawn from both literature searches and from public databases such as the Integrated Risk Information System (IRIS). Hazard information including carcinogenicity, chronic health hazard and developmental toxicity was compiled when available. Aquatic toxicity data were taken from literature when available but otherwise structure activity relationships were used to estimate six types of aquatic toxicity. Release and exposure estimates were based on values derived from product usage and work practices information obtained from the Workplace Practices Questionnaire completed as part of the DfE project as well as industry sources.

Performance Demonstration Methodology

To collect performance and cost information on alternative screen reclamation products, EPA's Office of Research and Development and the DfE Program conducted a demonstration of the performance of alternative screen reclamation products.
This type of analysis is not usually part of the work done by the Office of Pollution Prevention and Toxics' Existing Chemicals Program. The performance demonstration methodology summarizes how performance information was collected during both laboratory and production run demonstrations with alternative screen reclamation products. The methodology was developed jointly by EPA, screen printers, and product manufacturers and it governs the demonstration of products in the laboratory and in the field.

Performance data were collected for 11 alternative screen reclamation product systems and one alternative technology. First, performance data were collected for the alternative product systems in a laboratory setting at The Screen Printing Technical Foundation (SPTF). Then, in thirty-day production runs at 23 volunteer facilities field performance information was collected on alternative screen reclamation systems, including information on the time spent on ink removal, volume of products used, and appearance of the screen following each step in the reclamation process. It should be noted that the performance demonstrations are not rigorous scientific investigations. Instead, a large portion of the performance information outlinesthe printers' experiences with and opinions of these products as they were used in production runs at their facilities. The DfE Program will be developing four performance demonstration case studies for distribution to industry based on the more effective demonstrations.

Chemical Usage Methodology

Since there was no resource available providing specific screen reclamation chemical volumes or cost information, the DfE Program worked with industry to develop techniques to estimate both the chemical volume and basic cost information for the methods evaluated. Chemical volume information is necessary to complete both the cumulative exposure estimates and the basic cost comparisons.

The methodology for determining chemical usage summarizes the assumptions and calculations used to estimate the annual national totals of chemicals used in screen reclamation. *The Use Cluster Analysis of the Printing Industry* and The Workplace Practices Questionnaire for Screen Printers developed as part of the DfE Printing Project, the *Screen Printing Association International 1990 Industry Profile Study* and expert opinion estimates, were used to develop an estimate of the chemical volumes. The information needed to develop the estimates included the average screen size, the per screen volume of each type of reclamation product, market shares, the number of screens cleaned yearly, and the number of screen printing operations. The screen size, in conjunction with the amount of product used or purchased and the number of screens cleaned, was used to determine the per screen product usage. Typical formulations were then used to determine the chemical breakdown of the reclamation products. Combining this information resulted in estimates of the volumes for each of the chemicals involved in screen reclamation.

Cost Analysis Methodology

A cost methodology was developed to estimate the costs of baseline screen reclamation, as well as the cost of six alternative chemical, technological and work practice substitutes. The cost estimation methodology is intended to reflect standard industry practices and uses representative data for the given screen reclamation substitutes. For each substitute method, annual facility costs and per screen costs were estimated for individual facilities (those involved in the performance demonstrations) whose operations were characteristic of the given substitute method. For the hypothetical baseline facility, the total annual cost and per screen cost were estimated for reclaiming six screens (2,127 in^2 or 14.7 ft^2) per day. In addition, each facility's costs were normalized to allow cross-facility comparisons, particularly with the baseline scenario. Normalized values adjust product usage, number of screens cleaned, and number of rags laundered at demonstration facilities to reflect the screen size and number of screens cleaned per day under the baseline scenario.

Functional Groups in Screen Reclamation

The Screen Reclamation CTSA devotes two chapters to the subject of comparative risk. Chapter 4, focuses on screen reclamation *products*, while Chapter 5 focuses on screen reclamation *systems*. Chapter 4 presents cost and risk information by functional group (i.e., different ink removal product formulations) where the products evaluated might be simply substituted for one another. The evaluations in Chapter 5 focus on systems of products comparing both the formulations of the products within those systems and the changes in the methods used to clean screens.

In Chapter 4, information on the characteristics associated with each of the ink remover, emulsion remover and haze remover products is presented in a format that would allow comparison of several types of products within each functional group. For example, 13 different formulations were evaluated for ink removers.

For each type of product (ink removers, emulsion removers and haze removers), several pieces of information are provided: chemical properties (flash point, percent VOC, vapor pressure), hazard summary (health effects description and aquatic hazard rankings), purchase cost, occupational exposures and risk conclusions, environmental releases and population exposure conclusions. A process safety hazard evaluation was not included but could be an important consideration. For example, when substituting one product for another to avoid a health concern, the new product might have fire hazard issues. A safety hazard evaluation should be included in future CTSAs.

Information on total cost and product performance is not provided on product basis but rather on a system basis. These products are typically sold as a system and more complete cost and performance information is provided in Chapter 5 where systems of products are evaluated.

One of the more important inputs required to conduct a comparative risk assessment is product chemical formulation information. Since EPA is not developing specifications or labeling standards for products, the DfE Screen Printing Project did not believe it was necessary to give product names or to release proprietary formulation information to other product manufacturers or to the public. To make the CTSA usable and flexible, the DfE Program, in conjunction with the screen printing manufacturers and the Screen Printing Association International devised a standard format that includes generic product formulations and product names. The generic formulations and names allow the users of the CTSA to compare chemical constituents in product systems in a range of volumes while protecting the proprietary nature of the product formulations. Therefore, the chemical formulations for the products in the functional groups are not all-inclusive and other formulations may be available commercially.

Substitute Comparative Assessment of Screen Reclamation Systems

Chapter 5 in the CTSA compiles comparative risk, cost and performance data on complete screen reclamation product systems. This comprehensive assessment details four screen reclamation methods and the automatic screen washer and serves as the backbone of the CTSA. Information is provided for each method and technology on occupational exposure and risk, population exposure and risk, performance of traditional and alternative systems, and the analysis of cost of traditional and alternative product systems when available. Table ES-1 summarizes the cost and risk trade-offs for the methods evaluated.

Method 1

Method 1 encompasses the use of only ink removal and emulsion removal products to reclaim screens. The action of these two products can eliminate the use of a haze remover; some screen printers are able to reclaim screens without the need for a haze remover. Eliminating the haze remover achieves the highest priority in the pollution prevention hierarchy, source reduction. Six systems were assessed that can be used with this method. Many of these systems can also be used with a haze remover and are also included under method 2.

Method 2

In a typical screen printing facility, ink remover, emulsion remover and haze remover are all used in the process of screen reclamation. Method 2 incorporates the most common practices in screen reclamation. For the purposes of determining occupational exposure to the haze remover, it was assumed that screen reclaimers only used haze remover on 1-2 screens of the estimated six screens reclaimed daily in the average small/medium screen printing facility. Because Method 2 is the most representative of current screen reclamation practices, 14 systems are assessed that use this method including four traditional systems and ten alternative systems.

Method 3

Method 3 was developed by technical staff at SPAI and is currently taught at SPAI in workshop classes; it is referred to by the name "SPAI Workshop Process." It differs from Method 1 in that screen degreasers and ink degradants are used in the screen reclamation process. Method 3 also differs from Method 2 in that no haze remover is necessary. Technical staff at SPAI developed this method specifically to avoid the use of haze removers, which can damage the screen meshes well as contribute to human health and environmental risks. Only one system was assessed using this method. Due to resource limitations, no performance demonstration was completed for this method. However a cost assessment was completed and issummarized table ES-1.

Method 4

Method 4 is currently in use in screen printing facilities as an alternative to traditional screen reclamation. Method 4 utilizes the action of a high-pressure water blaster (3000 psi) so that the need for ink removal chemicals is eliminated. Emulsion and haze remover chemicals are still applied to the screen, and the water blaster also aids in removal of stencil and haze. Because an ink remover is not used in screen reclamation in Method 4, source reduction, the highest priority in the pollution prevention hierarchy, is achieved. Again, only one system was evaluated using this method.

Automatic Screen Washer

Automatic screen washers are commercially available technologies that remove ink, or in some cases, ink, emulsion and haze, by focusing appropriate reclamation products on a screen mesh surface within a fully enclosed unit. The system can be selective, in that it can be used to remove ink only, or to completely reclaim screens. These units employ facets of the washout booth, pressurized sprayer/applicator, and filtration system to effectively remove ink. Because these systems have a fully enclosed cleaning area, the amount of occupational exposure to the chemical reclamation system in use can be minimized if used properly.

Due to the lack of manufacturer participation, the demonstration of the performance of an automatic screen washer was not undertaken. However, a risk assessment was developed for an automatic screen washing system used by a facility that participated in the performance demonstration; this screen washer only removed ink. Experimental parameters used in the occupational exposure and population exposure calculations were drawn from the data available from this single site. The risk assessment could not be undertaken for the actual solvents used in the screen washer as the composition of the ink remover was unknown. Instead, two typical ink remover formulations were substituted to complete the assessment of releases and risk. Also two cost estimates were developed to reflect different facility operations and size. One estimate reflects a large enclosed system with automated movement of screens through the cleaning process. The other estimate was conducted for a smaller piece of equipment requiring manual loading and unloading of screens, as well as water rinsing of residual ink remover.

Screen Disposal as a Method of Pollution Prevention

During the course of the assessment of various screen reclamation methods, it was proposed that disposal of imaged screens, rather than reclamation might be a feasible alternative. It was known that some screen printers with long production runs and extremely small screens, such as those used to print on medicine bottles, simply cut the screen mesh out of the frame after completion of the production run. By simply disposing of the screens, printers could eliminate the high cost of reclamation chemicals and labor time associated with screen reclamation, as well as reduce the risk associated with occupational and population exposure to these chemicals. Conversely, printers would have to dispose of more screens, with the potential for some screens to be designated as hazardous waste due to the chemicals applied to them during imaging and printing. Due to the different types of source reduction involved in these two options, they are difficult to directly compare in terms of pollution prevention. To determine whether screen disposal was a cost-effective option, a cost estimate was developed to reflect the baseline facility's operations and size. It was estimated that the total cost per year of disposing of the screens, instead of reclaiming them, would be $74,141. The baseline cost of reclaiming screens for a year was estimated at $9,399. Based on this analysis, it is clear that screen disposal is not a cost-effective option for a majority of screen printing facilities. However, printers should not view this cost estimate as a final analysis, because the operations of any one facility can be different from the assumptions used in generating this analysis. It should be noted that screen disposal would be more cost-effective under two circumstances that were not included in the baseline facility estimates: where production runs approach the useful life of a screen and where the size of the screen is relatively small.

Summary of Risk Conclusions

The general conclusions for estimated risks from screen reclamation are outlined below. As presented, the risk conclusions are for all of the methods, unless stated otherwise.

- Estimated worker dermal exposures to traditional and alternative screen reclamation products can be high if proper protective clothing is not worn.

- All of the traditional products presented clear concerns for both inhalation exposures and unprotected dermal exposures to workers.

- Only one of the alternative products (mu) presented a clear concern for inhalation exposures to workers. In general, the alternative products are much less volatile than the traditional products, and, therefore, have fewer releases to air.

- Health risks to the general population from ambient air and drinking water exposures are estimated to be very low for all of the products evaluated due to low quantities of releases from individual sites.

- The major health impact on the general population for screen reclamation products is probably its release of volatile organic compounds that contribute to the formation of photochemical smog in the ambient air. The traditional products, because of their volatility, are likely to have a much greater impact than the alternative products on ambient air quality.

- Use of an automatic screen washer for ink removal may significantly reduce air emissions of certain volatile ink remover components, although the amount of reduction depends on the specific components of the formulation. However, the automatic screen washer is expensive and is probably unaffordable for most screen printers.

Performance and Cost Summary

In Chapter 5, immediately following the risk assessment of each product system, is a detailed performance summary. It includes a general summary of product performance, a description of the product application method, results from the evaluation at the Screen Printing Technical Foundations (SPTF), details of product performance reported separately for each volunteer printing facility, and facility background information. For each product system, a table is also included which provides certain summary statistics from the performance demonstrations at the volunteer printing facilities and at SPTF (for three ink types). For a quick summary of the results, the table providing summary statistics (Chapter 5) is very helpful.

In general, the alternative products performed similarly to traditional products but with generally lower costs and generally more risk reduction than the traditional products. Three systems/technologies consistently met the expectations of printers: Epsilon, Chi and Theta. Delta, Mu and Phi also received mostly favorable reviews. Product Systems Alpha and Omicron AF, as well as ink remover Beta, received mixed reviews, with performance documented as acceptable at some facilities and unacceptable at others. Performance of Gamma, Omicron AE, and Zeta was deemed unacceptable at the facilities that used these product systems. A performance assessment of one traditional system, Traditional System 3, was also conducted; this evaluation was only completed at SPTF. The performance of the products varied greatly with the different ink types; the lacquer thinner removed the ink on screens printed with UV-curable and solvent-based inks, but was completely incompatible with water-based ink. In the case of the screen printed with solvent-based ink, the sodium hypochlorite (bleach) solution used as an emulsion remover caused the screen mesh to rip.

Table ES-1 summarizes the cost and hazard issues by method and system for the alternative systems. Summaries for the baseline method used in the cost estimates is given followed by the four major methods of screen reclamation, automatic screen washer and simple disposal of the screens without reclamation. Within the four primary screen reclamation methods the various systems that can be used with those methods (e.g., alpha, chi, delta, etc.) are listed with the cost and risk summaries. This table presents summaries only, for a more complete description of the costs and exposure and hazard issues consult Chapter 5.

Overall Pollution Prevention Opportunities in Screen Reclamation

Pollution prevention, or source reduction, is the reduction of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment. Pollution prevention can be accomplished through activities such as material substitution, process improvements, changes in workplace practices and in-process recycling. The primary focus of the CTSA through Chapter 5 is on material substitution, Chapter 6 lists ways to achieve pollution prevention and risk reduction through improved workplace practices and equipment modifications.

Pollution Prevention Through Improved Workplace Practices

In an effort to help industry think of pollution prevention options that might be available to them and that do not require changing chemical products, the Screen Reclamation CTSA provides information on improved workplace practices. The basic framework for pollution prevention through improved workplace practices involves:

- raising employee awareness;
- materials management and inventory control;
- process improvement; and
- periodic, in-house audits.

Table ES-1
Costs and Risk Trade-offs of Screen Reclamation Substitutes

System Evaluated		Cost/Screen	Cost/Facility	Risk Trade-offs
Baseline for Method 1 (Traditional System 4 - Haze Remover)		$3.63	$5,446	Clear concern for worker dermal risks and worker inhalation risks
Method 1: Chemical substitutes for ink removal and emulsion removal. No haze removal required.	Chi (no haze remover)	$1.95-2.83	$2,918-4,245	Moderate concern for worker dermal risks and very low concern for inhalation risks
	Beta	$7.97	$11,958	
Baseline for All Other Methods (Traditional System 4)		$6.27	$9,399	Clear concern for worker dermal risks and worker inhalation risks
Method 2: Chemical substitutes for ink removal, emulsion removal and haze removal.	Alpha	$5.92-9.37	$8,886-14,062	Moderate concern for worker dermal risks and low concern for inhalation risks
	Chi	$3.25-3.89	$4,879-5,829	
	Delta	$3.28-7.66	$4,917-11,489	
	Epsilon	$3.08-5.29	$4,624-7,930	
	Gamma	$5.06-5.61	$7,590-8,417	
	Mu	$4.79-9.33	$7,185-13,997	
	Phi	$6.10-7.82	$9,233-11,728	
	Omicron-AE	$5.49-10.85	$8,240-16,278	
	Omicron-AF	$3.89-4.45	$5,836-6,675	
	Zeta	$5.39-8.99	$8,080-13,479	
Method 3: Chemical substitutes for ink removal, degreasing and emulsion removal. No haze removal required.	Omicron	$5.57	$8,358	Moderate concern for worker dermal risks and very low concern for inhalation risks
Method 4: Technology substitute of screen disposal in lieu of reclamation.	Theta	$4.53	$6,797	Marginal concerns for worker dermal risks and very low concerns for worker inhalation risks
Technology Substitute	Automatic Screen Washer	$4.13-10.14	6,198-15,213	Moderate concern for worker dermal risks and very low concern for inhalation risks
Work Practice Substitute	Screen Disposal	$49.43	$74,141	No risks associated with screen reclamation products

Note: Costs presented are normalized costs. Ranges are presented when there was more than one facility using the method and system in the performance demonstration.

Raising employee awareness may be the best way to get employees to actively participate in a pollution prevention program. Materials management and inventory control means understanding how chemicals and materials. With this information opportunities for pollution prevention can be identified. Process improvement through workplace practices requires re-evaluating the day-to-day operations that make up the printing and screen reclamation processes with the goal of waste minimization and pollution prevention. Finally, in-house audits can be used to collect real-time data on the effectiveness of a pollution prevention program. These efforts can give both operators and managers the incentive to strive for continuous improvement. Table ES-2 lists some workplace practices that prevent pollution and describes the benefits associated with them.

Pollution Prevention Through Equipment Modifications

In addition to workplace practices, several types of equipment can be used in screen reclamation to prevent pollution. Such equipment includes sprayer/applicator systems, washout booths, filtration systems, recirculation systems and distillation units. Illustrative examples of each of these systems, as well as explanatory text, are outlined in Chapter 6 of the CTSA.

The use of sprayer/application systems to apply screen reclamation chemicals to the used screen may reduce losses and potential exposures with more effective application. A washout booth can also minimize exposures and waste by containing the reclamation process in a confined area and collecting spent chemicals for proper reuse or disposal. Filtration systems can be used to remove specific substances from the waste stream facilitating compliance and allowing the reuse of some chemicals. Recirculation systems are generally required to reuse captured chemicals. Typically, recirculation systems are used in conjunction with filtration systems, washout booths and/or sprayer application systems. Distillation devices can provide an effective means of recycling and reusing spent solvents.

Many of these systems can save money as well as facilitate compliance and prevent pollution by reducing the amount of chemicals used in screen reclamation. Each printer would need to examine his or her particular process to determine the applicability of any or all of the above equipment modifications. In addition printers should consult applicable water and waste disposal regulations to ensure compliance before making equipment changes.

Social Cost/Benefits of Alternative Screen Reclamation Processes

A summary of various macroeconomic considerations, including energy and natural resource considerations and a social costs/benefits analysis complete the Screen Reclamation CTSA. These considerations allow printers to put into perspective their contributions to environmental problems by discussing the aggregate impact issues.

Table ES-2: Workplace Practices and Their Benefits

Workplace Practices	Benefits
Keep chemicals in safety cans or covered containers between uses	Reduces materials loss; increases worker safety; reduces worker exposure
Use plunger cans, squeeze bottles or specialized spraying equipment to apply chemicals to the screen	Reduces potential for accidental spills; reduces materials use; reduces worker exposure
Consider manual, spot-application of chemicals, where applicable	Reduces materials use; reduces worker exposure if aerosol mists are avoided
Use a pump to transfer cleaning solutions from large containers to the smaller containers used at the work station	Reduces potential for accidental spills; reduces worker exposure
Reduce the size of the towel or wipe used during clean-up	More efficient use of the towel; reduces solvent use; reduces worker exposure
Reuse shop towels on the first pass with ink remover	Reduces material (shop towel and ink remover) use; reduces worker exposure
Evaluate alternative chemical: water dilution ratios (increase the amount of water)	Reduces chemical usage with no loss of efficiency; reduced worker exposure
Only apply chemicals where necessary	Reduces chemical usage; reduces worker exposure
Avoid delays in cleaning and reclaiming the screen	Simplify ink and emulsion removal; less potential for haze on the screen
Gravity-drain, wring, or centrifuge excess solvent from rags	Recovers solvent for reuse
Place catch basins around the screen during the screen cleaning/reclamation process	Captures chemical overspray for recovery and reuse
Use appropriate personal protective equipment (gloves, barrier cream, respirator, etc.)	Reduces worker exposure

Energy and Natural Resource Considerations

When designing products or processes with the environment in mind, conservation of energy and natural resources (e.g., materials) should also be a goal. The Screen Reclamation CTSA identifies the areas where energy and materials are consumed as a result of the screen reclamation process. For screen cleaning and reclamation chemicals, the DfE Screen Printing Project elected to focus on energy and natural resource consumption during the use stage, when printers are actually cleaning and reclaiming their screens. The data collected during the performance demonstration did not allow for clearcut extrapolation because of the variety of conditions present in screen printing shops. As a result, quantitative analysis was not possible. Summarized below are some of the areas where energy and natural resources may be consumed as a result of the screen reclamation process.

- During a water wash, the rate of energy use may be dependent on type of equipment used to apply the water. High-pressure spray washes may require more energy than a non-pressurized water wash.

- Also during a water wash, the use of hot or warm water washes are much more energy intensive than those conducted at ambient water temperatures.

- Another source of resource consumption is disposable shop towels. In addition to the consumption of resources, they also generate solid, potentially hazardous, waste and increased disposal cost.

Social Costs/Benefits Analysis

There are a variety of issues that need to be considered when assessing the overall cost to society that screen reclamation imposes. Many of the issues cannot be quantified but they ought to be included in the decision-making process. The social cost/benefits section in the Screen Reclamation CTSA offers a qualitative discussion of these issues.

The risk assessment conducted as a part of the CTSA analyzed the risk of both traditional and alternative screen reclamation systems using four different methods. Automatic screen washing and simple disposal of the used screens was also examined. A cost analysis was performed to estimate the cost of each alternative screen reclamation method, technology, and work practice evaluated in the CTSA. The social cost/benefits analysis compares in general terms the costs and benefits (in terms of reduced human health risks) of switching to alternative screen reclamation products, technologies, and work practices. In addition, this analysis looks beyond just the costs (material, labor, etc.) and benefits (reduced worker health risks) to printing operations of switching to alternative product systems and considers the potential for benefits to society as a whole. Specifically, it considers the possibility that the use of screen reclamation substitutes could result in reduced health risks to the general population, lower health insurance and liability costs for the printing industry and society, and decreased adverse impacts to the environment. Based on this analysis, the following conclusions were drawn.

- The population of workers exposed to screen reclamation products in the graphics section of the screen printing industry is estimated to be as low as 20,000 or as high as 60,000 depending on how many workers at each facility spend part of their time reclaiming screens.

- The major benefit identified for switching from traditional screen reclamation methods to alternative methods is a significant reduction in inhalation risks to workers.

- Among the chemical substitutes evaluated, labor was the largest portion of the reclamation cost. For the technology and work practice substitutes, equipment and materials constituted the largest portion of the reclamation cost. Alternative products, however, did not necessarily have greater labor costs as compared to traditional products. Rather the labor costs tended to depend on the mix of chemicals and technologies (i.e., high pressure sprays) selected.

○ The estimated cost associated with using the baseline traditional screen reclamation system equaled $3.63/screen for method 1 and $6.27/screen for all other methods.

○ Under the alternative systems, estimated costs range from $1.95/screen ($2,918 per year) for Method 1 to $10.85/screen (Omicron-AE, Method 2).

○ For all systems overall, alternative products are estimated to be less costly than traditional systems depending on the technologies used (see table ES-1).

○ The social benefit of switching to alternative screen reclamation products includes the benefit to society of reduced risk from exposure to such hazardous wastes during transport to landfills and in the event of migration of contaminants from the landfill into groundwater. Printers may also receive benefits in the form of reduced hazardous waste disposal costs since for most of the alternative product systems, there might not be any hazardous waste. It should be noted that determination of hazardous wastes was based on ignitability of chemical constituents; toxicity testing could result in a different classification of the wastes as hazardous.

A more complete discussion of the social costs and benefits is included in Chapter 7 of the CTSA.

Conclusion

The appendices include a glossary of terms used in the environmental fate summaries. Also included is a sample questionnaire from the Workplace Practices Questionnaire and the basic results of the survey. The evaluation sheets for both the observers and the participants in the performance demonstration are also included. Finally, general methodology data and a description of some of the models used are included in the appendices.

The draft of the Screen Reclamation Cleaner Technologies Substitutes Assessment is being released for public review and comment for 90 days. After which, comments will be incorporated and a final version of the Cleaner Technologies Substitutes Assessment will be released in the spring of 1995.